



# A Comparison of ARTEMIS Data with the Lunar Plasma Design Environment for NASA Crewed Missions

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# Overview

- Goal – Determine if the existing lunar plasma environment definition is sufficient for NASA's Gateway and Lander missions
- Method – Compare ARTEMIS data with the existing lunar plasma environment definition
- Results – Initial observations of ARTEMIS data show some differences with the existing definition, particularly in the lunar wake and locations in the magnetosphere
- Conclusion – A full statistical analysis of ARTEMIS data is needed in order to fully characterize the lunar environment

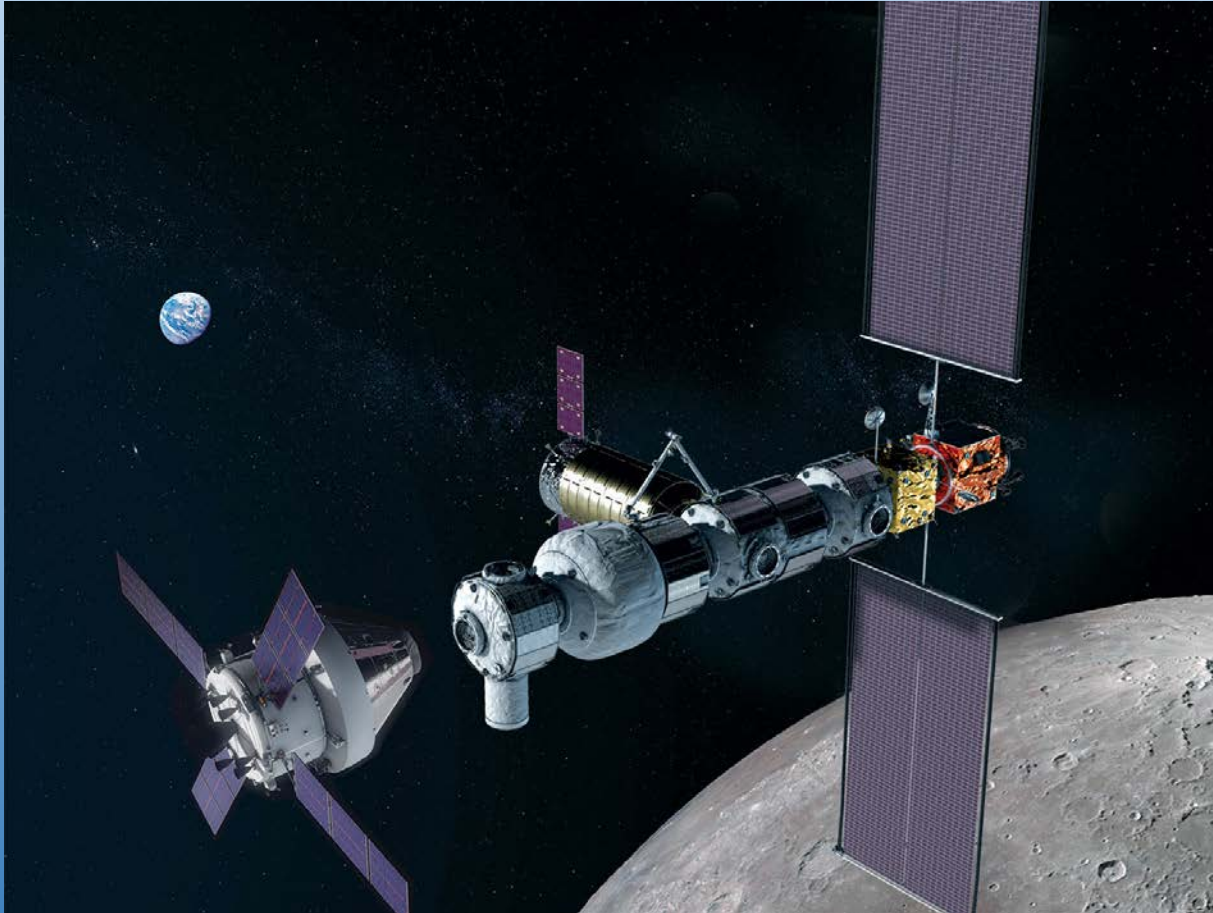


# Outline

- Overview of NASA's Gateway, ARTEMIS, and Spacecraft Charging
- Existing Lunar Plasma Environment Definition
- ARTEMIS Data Comparison with DSNE
- Conclusions
- Forward work



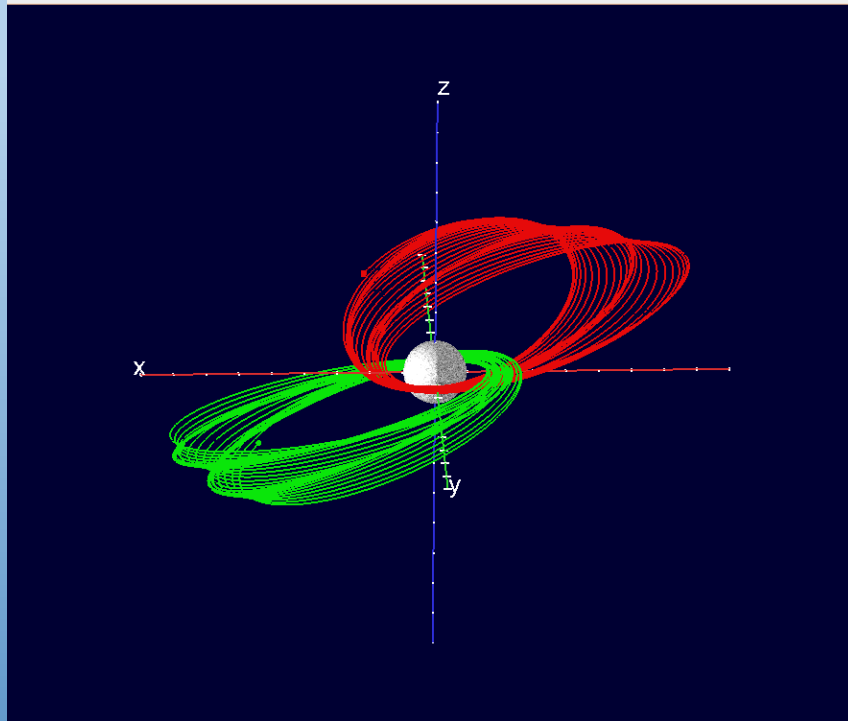
# NASA's Gateway<sup>1</sup>



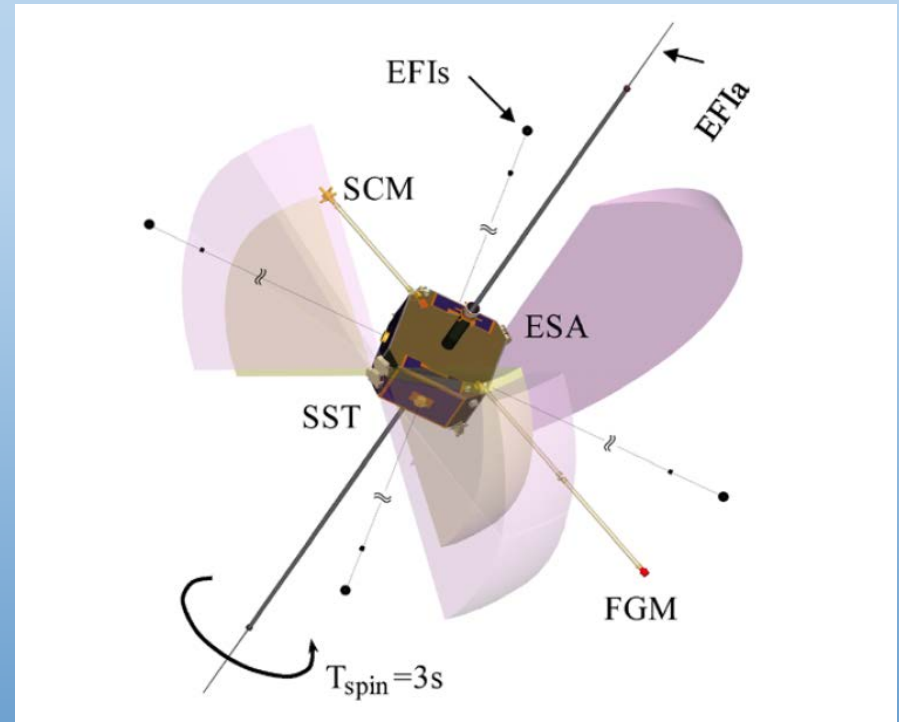
- Orbit: 2500km x 75000km Near Rectilinear Halo Orbit (NRHO) (*not final*)
- Elements: Power and Propulsion, Habitat, Docking, Visiting Vehicles (Orion), Solar Arrays
- Operations: Dockings, Maneuvers, EVAs, Solar Arrays



# ARTEMIS<sup>2</sup>



- Orbit:
  - 26 hour period
  - Lunar wake crossings from a wide range of altitudes.
  - Equatorial
  - 100km x 19,000km

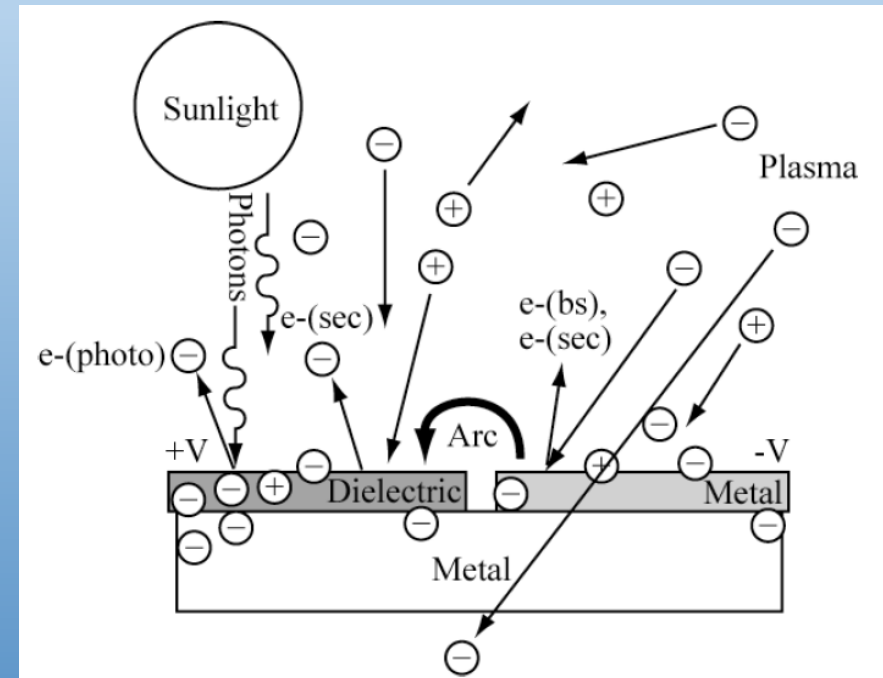


- Instruments
  - Electric Field Instruments
  - Fluxgate Magnetometer
  - Search Coil Magnetometer
  - Axial and Spin Plane Electric Field Sensors
  - Solid State Telescope
  - Electrostatic Analyzer



# Spacecraft Charging<sup>3</sup>

- The amount of charge collection to surfaces depends on:
  - Ambient plasma
  - Photoemission
  - Secondary electron emission
  - Backscattering
- Material dependent, design dependent
- Photoemission and secondary electron emission are significant contributors in cislunar space





# The Moon

“a fundamental physics laboratory”<sup>4</sup>

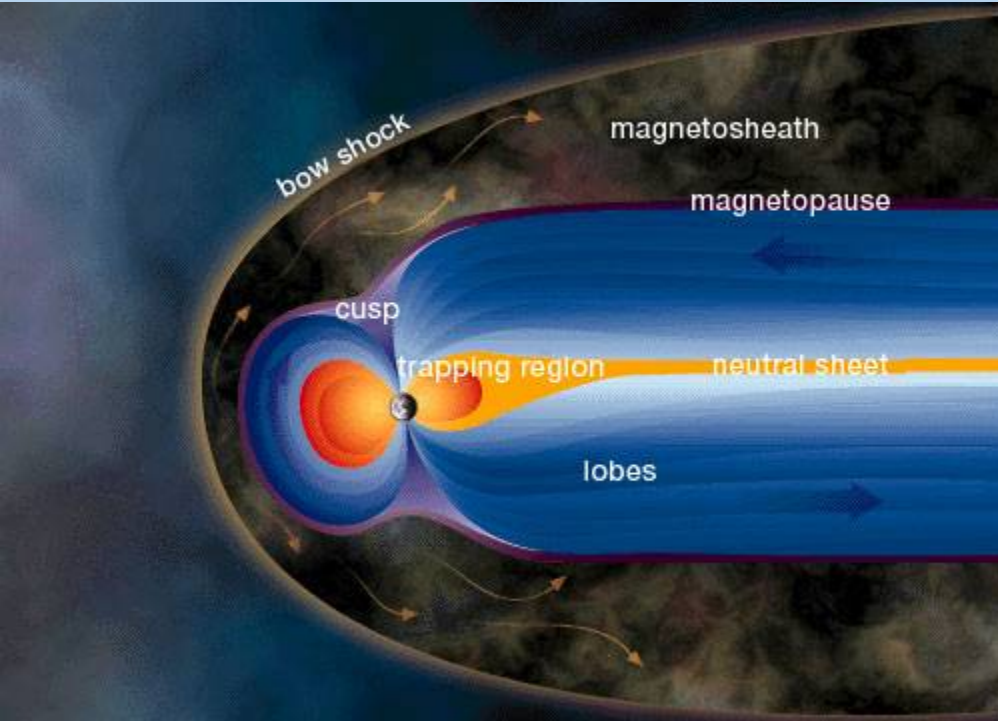


Image Credit: CCMC web

***Our challenge is to describe the environment in a way that is useful for spacecraft design.***

- No significant atmosphere
  - Weak surface boundary exosphere
- No significant global magnetic field
  - Regions of crustal magnetism
- Solar Wind (73% of orbit)<sup>5</sup>
  - IMF inductive effects
  - Wake
  - Downstream diamagnetic currents
- Magnetosheath (14% of orbit)<sup>5</sup>
  - Plasma dominated by exosphere
- Magnetotail (13% of orbit)<sup>5</sup>
  - Plasma Sheet interactions and magnetic reconnection.





# Existing DSNE Environment<sup>5</sup>

**Table 3.3.3.4-1. Interplanetary Environment Plasma Parameters**

	Electron Density	Electron Temperature	Ion Velocity	Ion Density	Ion Temperature
	m <sup>-3</sup>	eV	km/s	m <sup>-3</sup>	eV
Magnetosheath / magnetotail	10 <sup>6</sup> - 10 <sup>8</sup>	10-2000	400-1000	10 <sup>6</sup> - 10 <sup>8</sup>	10-10,000
Solar Wind	10 <sup>5</sup> - 10 <sup>8</sup>	12	400-1000	10 <sup>5</sup> - 10 <sup>8</sup>	50



**Table 3.3.3.5-1. Lunar Wake Plasma Parameters**

	N <sub>e</sub> /N <sub>e0</sub>	T <sub>e</sub> /T <sub>e0</sub>	N <sub>i</sub> /N <sub>e</sub>	T <sub>i</sub> /T <sub>e</sub>
Wake 150°	0.005	7.6	0.1-1	0.01-1
Wake 180°	0.003	4.5	0.1-1	0.01-1



Nascap2k - D:\LEOGateway\Nascap\Box\BoxProject.xml

File Edit View Materials Help

Problem Environment Applied Potentials Charging Space Potentials Particles Script Results Results 3D

### Interplanetary Environment

**Interplanetary Environment Plasma**

Electron Density (m<sup>-3</sup>): 1E5

Electron Temperature (eV): 1000

Ion Density (m<sup>-3</sup>): 2E6

Ion Temperature (eV): 200

Electron Thermal Current (Am<sup>-2</sup>): 8.477E-8

Ion Thermal Current (Am<sup>-2</sup>): 1.769E-8

**Magnetic Field (T)**

Bx: 0.0 By: 0.0 Bz: 0.0

**Spacecraft Velocity with Respect to Plasma (m/s)**

Vx: 0.0 Vy: 0.0 Vz: 0.0

**Sun**

Direction to Sun

X: 1.000 Y: 0.0 Z: 0.0

Relative\* Sun Intensity: 1.000

\* (value at Spacecraft) / (value at Earth Orbit)

☐ Use photoemission spectra

**Particle Species**

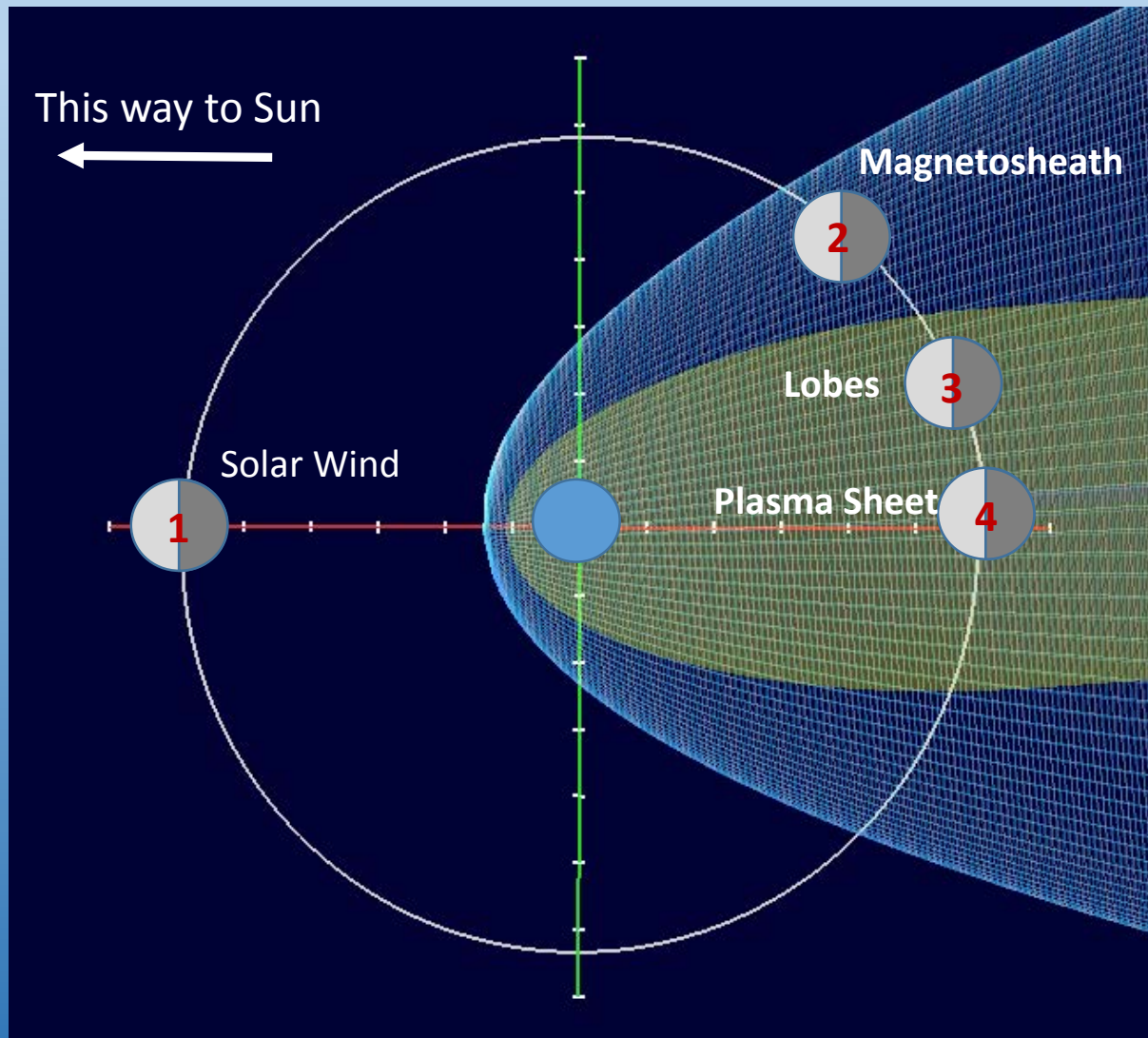
Type	Mass (amu)	Charge (C)	%
Electron	5.486E-4	-1.602E-19	100.0

Add Species Delete Species





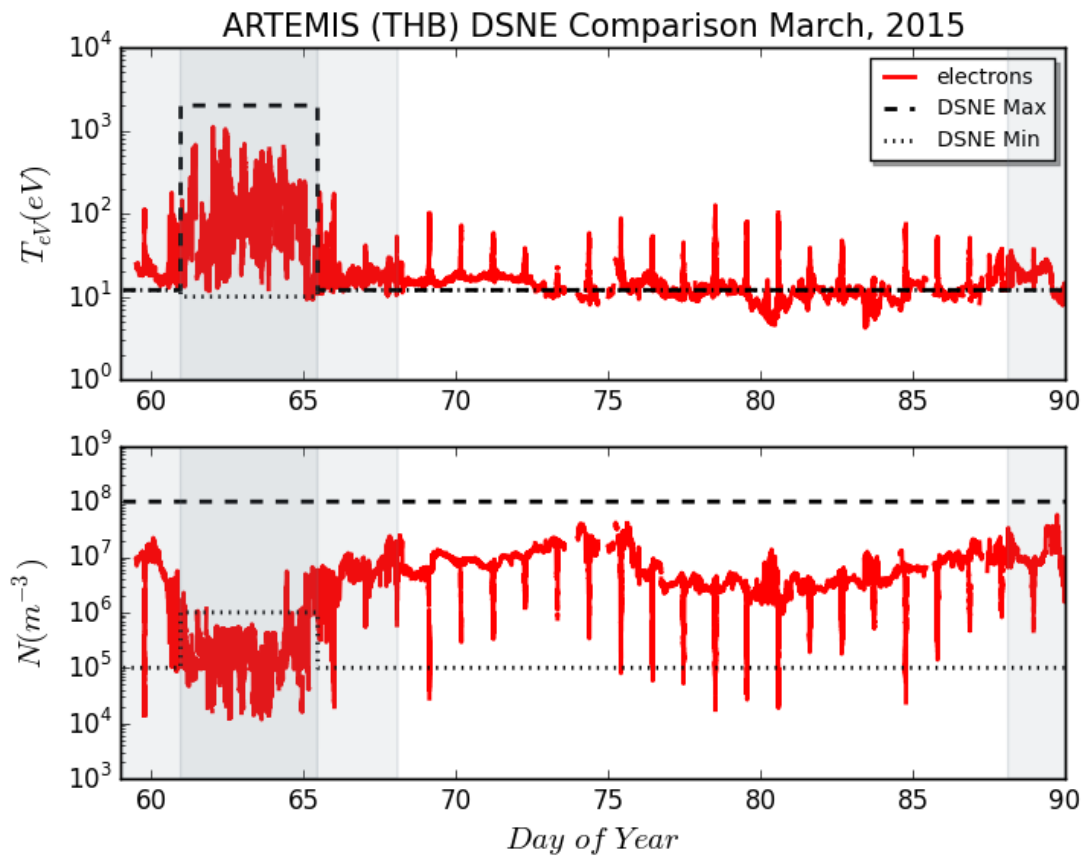
# Locations of Interest



- High Altitude
  - Sun Side
  - Dark Side
- Low Altitude
  - Sun Side
  - Dark Side
- Surface
  - Sun Side
  - Dark Side

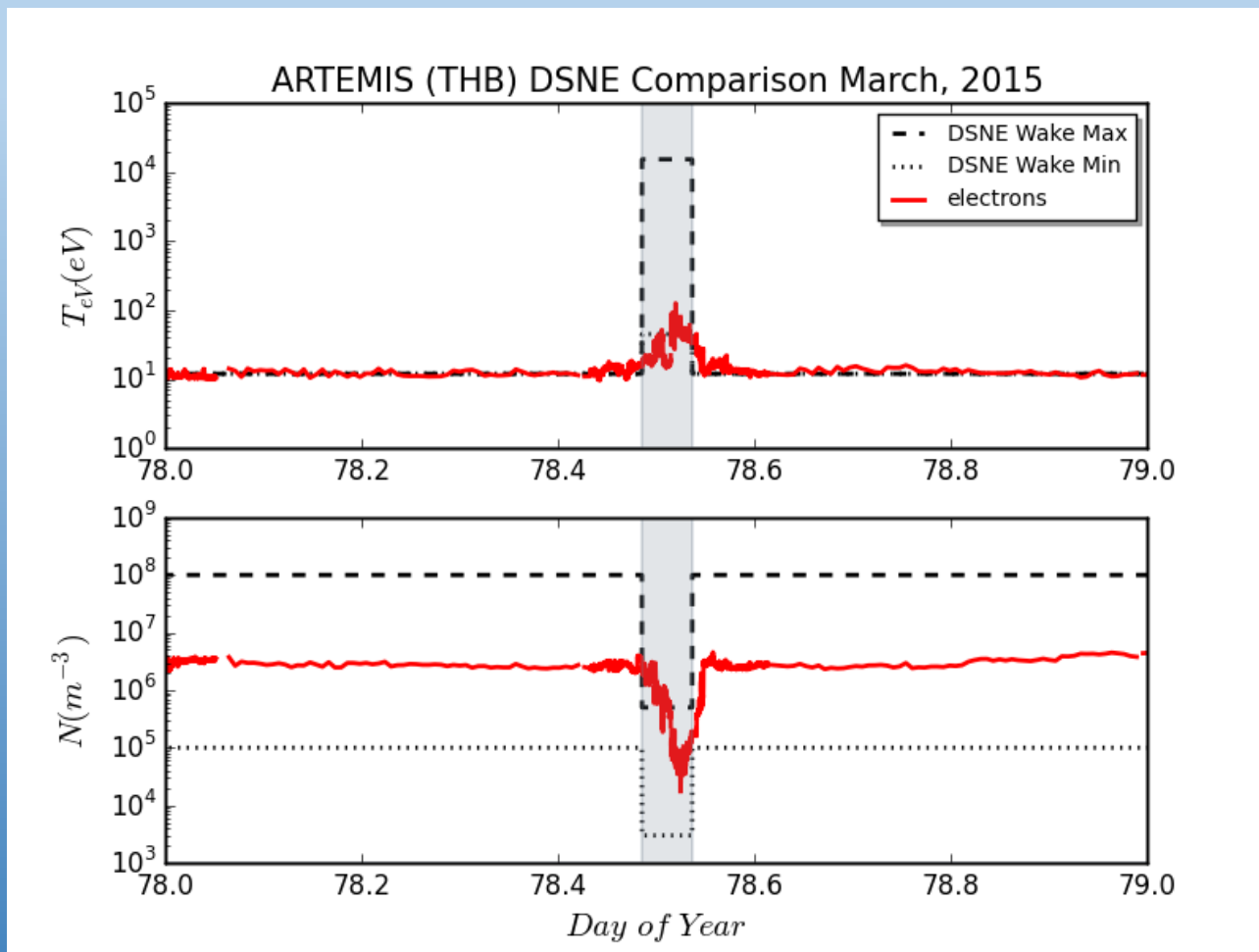


# ARTEMIS Electron Data



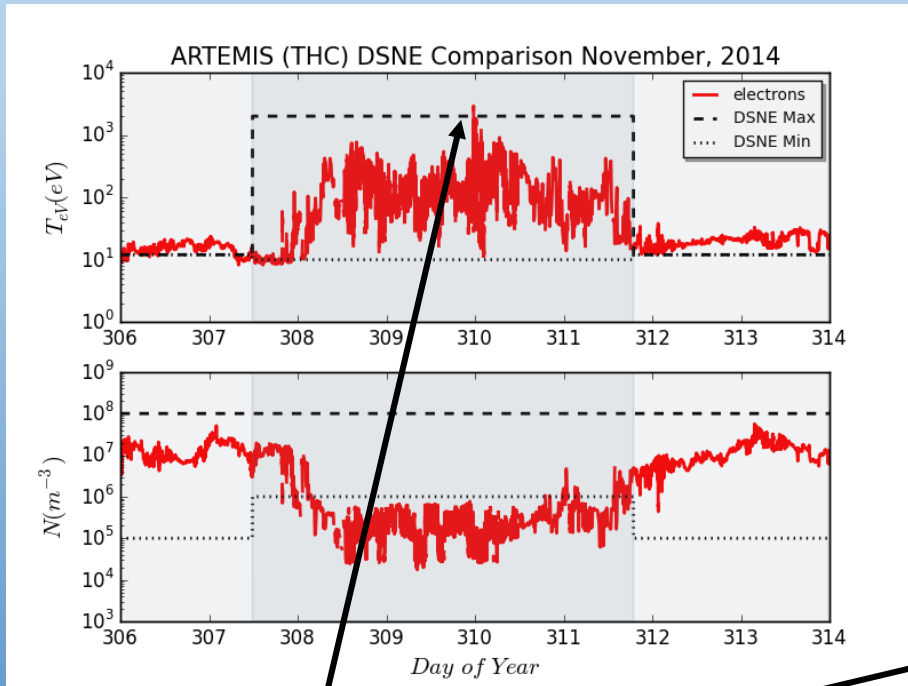


# ARTEMIS Lunar Wake Crossing

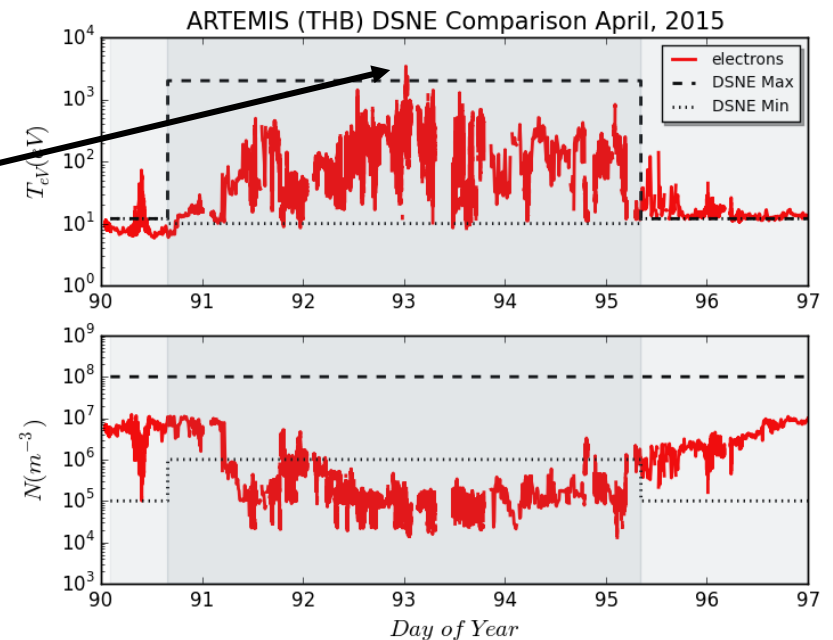




# Examples of Higher Electron Energy

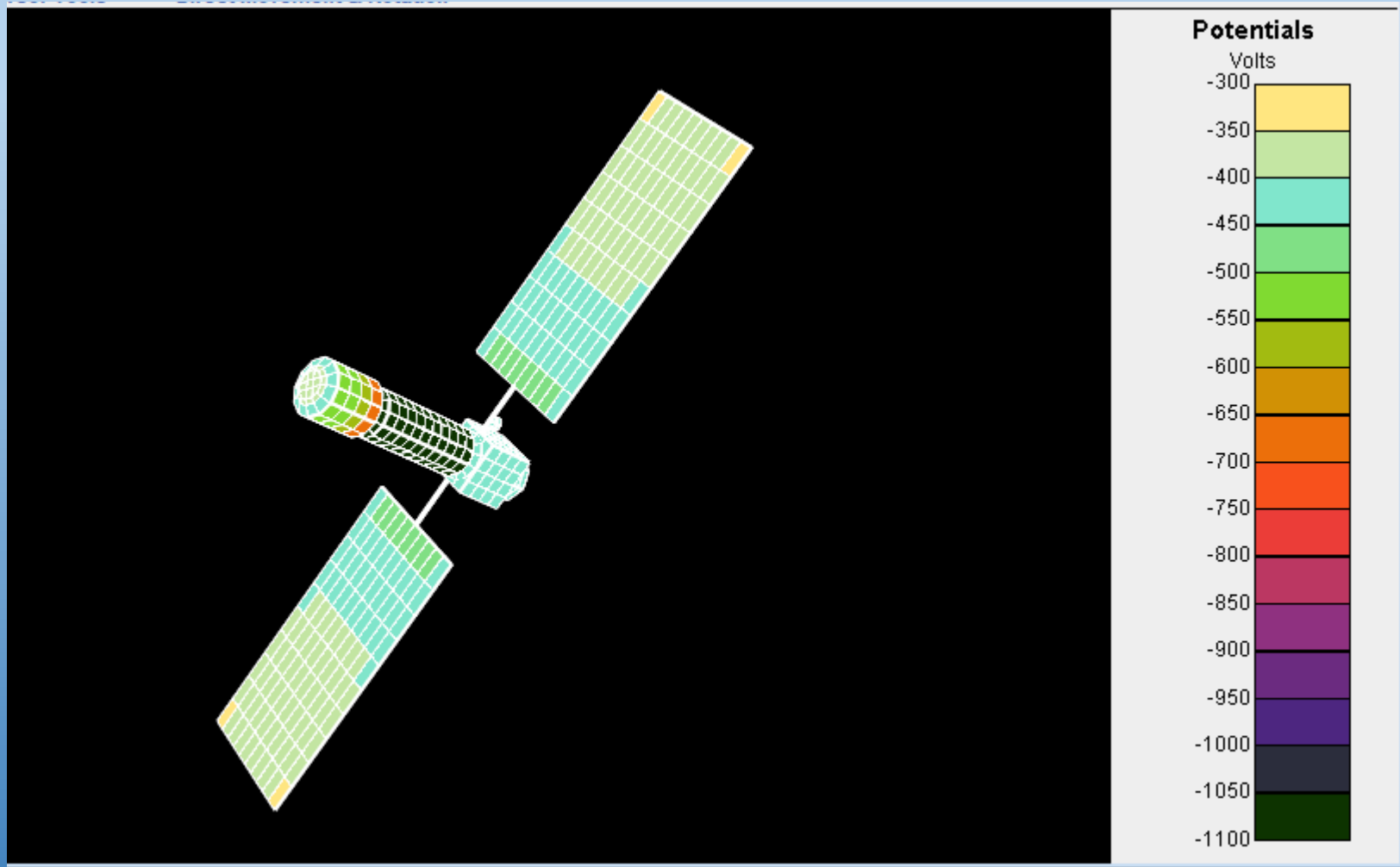


approximately 3000 eV





# Charging Analysis



Representative spacecraft in lunar orbit with dielectric and conductive surfaces

Model Credit: Gwyer Sinclair, MSFC EV44 Summer Intern



# Conclusions

- A statistical analysis of all ARTEMIS data is needed to fully characterize the lunar plasma environment for Gateway and Lander missions.
  - Average conditions
  - Extreme conditions
  - Range of altitudes
- Initial data observations show some disagreement with existing lunar plasma definition.
  - Lower density in the magnetosphere
  - Electron energy tends to stay below 2000 eV
  - High wake temperatures were not observed



# References

- [1] “Lunar Gateway.” [www.nasa.gov/mission\\_pages/station/main/index.html](http://www.nasa.gov/mission_pages/station/main/index.html), National Aeronautics and Space Administration.
- [2] Angelopoulos, Vassilis. "The ARTEMIS mission." The ARTEMIS mission. Springer, New York, NY, 2010. 3-25.
- [3] "NASA-HDBK-4002A: Mitigating in space charging effects—A guideline." [nrts.nasa.gov](http://nrts.nasa.gov). National Aeronautics and Space Administration
- [4] Halekas, J. S., et al. "New views of the lunar plasma environment." Planetary and Space Science 59.14 (2011): 1681-1694.
- [5] “Cross-Program Design Specification for Natural Environments (DSNE).” [nrts.nasa.gov](http://nrts.nasa.gov). National Aeronautics and Space Administration, Marshall Space Flight Center.